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Abstract

ISOTOPIC POWER SOURCES COUPLED WITH THERMOELECTRIC CONVERTERS

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Thermoelectric generators fueled with radionuclides are supplying power dependably today in space and remote terrestrial systems. This technology, developed under the aegis of the USAEC's SNAP Program (Systems for Nuclear Auxiliary Power), was shown to be feasible in 1959. Early operational status was achieved in 1961 when it was selected to provide power to a satellite and an unattended meteorological station 700 miles from the North Pole. Each system has logged more than 2 years of continuous trouble-free operation.

Power in these systems is obtained through absorption of the decay energy of the selected radioisotope and its degradation into heat. The thermal energy is then conveyed through a heat engine, such as a thermoelectric converter, producing electricity. Unconverted heat is rejected from the generator system, in a manner suited to the application of the device, e.g., radiation in space, and conduction and convection in terrestrial missions. In suitable combination, the technology yields a power supply that is extremely compact, reliable and light-weight, for lifetimes of 10 or more years in the power range of less than 1 watt to a few kilowatts. Space systems have already achieved power-to-weight ratios of greater than 1 watt per pound with the potential of doubling this figure in the next few years.

Design of the power system requires consideration of the application (space or terrestrial) and its lifetime, safety analyses, selection of the fuel (alpha- or beta-gamma-emitters), thermoelectric materials, insulation, shielding, heat-rejection mechanisms and power conditioning.

Useful radionuclide fuels are obtained from two sources: separated and purified fission products, or through neutron irradiation of target materials (e.g., curium-242 from irradiation of americium-241). Selection criteria include half-life, power density (thermal watts per cubic centimeter), physical and chemical form, cost and availability. Radioisotopes in the quantities required for power generation would create a hazard of some significance if improperly released to the biosphere. Safety, therefore, is a prime factor in establishing the practicability of this technology and assurance must be established for each application that the use of a power source will be harmless to man. Finally, a basic characteristic of a thermo-electric converter is that it is a high-current, low-voltage system requiring series connection of the thermo-electric elements to increase the overall voltage. A power conditioner is required to match the electrical out put of the generator to that of the payload. Static solid state power conditioners have been built operating at efficiencies up to 85% between 3 and 30 volts. These radionuclide fuels include Sr-90, Cs-137, Ce-144, Pu-238, Cm-242, Po-210 and Cm-244.

The United States has several of these power sources in various stages of development. They include Transit 4-A and -B (2.7 Watt, Pu-238), SNAP 9A (25 Watt, Pu 238), SNAP 11 (25 Watt, Cm-242), SNAP 13 (12 Watt, Cm-242), Weather station (4.5 Watt, Sr-90), SNAP 7A,C (10 Watt, Sr-90), SNAP 7E (6.5 Watt, Sr-90) and SNAP 7B,D (60 Watt, Sr-90). The performance of some of them now in operation is described with particular regard to power levels, efficiency, lifetimes, reliability and safety. Expected improvements in technology and unique applications of these devices are described.